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**TRACKING REVEALS LIMITED INTERACTIONS  
BETWEEN CAMPBELL ALBATROSS AND FISHERIES  
DURING THE BREEDING SEASON**

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## Abstract

The last century has seen a significant decline in global seabird populations that can, in part, be attributed to fisheries mortality. Understanding overlap between seabird distribution and fisheries is one important element in assessing the risk of bycatch, and may be achieved by tracking the movements of individual birds and fishing vessels. Here we assess the spatio-temporal overlap between the vulnerable Campbell Albatross *Thalassarche impavida* and large (>28m) commercial fishing boats in New Zealand's Exclusive Economic Zone (EEZ). We used bivariate Gaussian bridge movement models to compute spatio-temporal utilization distributions, both from high-resolution bird-borne GPS loggers and the Vessel Monitoring System, to estimate potential interactions with fisheries during the breeding season. During incubation and chick brooding, 49.7% of the 28,814.9 hours Campbell Albatrosses spent foraging were within New Zealand's EEZ, utilizing 6.7% of the available area. Within the EEZ, albatrosses only overlapped with fisheries vessels in a relatively small section in the southern portion of these waters. Despite this spatial overlap, there was no evidence that albatrosses and fishing vessels were in the same location simultaneously. When accounting for the broader ecological footprint of fishing vessels, which can influence bird behaviour for up to 30 km, we found albatross–vessel overlap in 8.4% of foraging trips. Overall, the low levels of spatial overlap could be a result of preference for foraging in areas without fishing activity or competitive exclusion by other species. While higher resolution data from both birds and vessels will improve our ability to detect the true nature of interactions, as opposed to just overlap, the current threat of bycatch during the breeding season appears comparatively low. Our results reinforce the importance of a multi-scale approach to risk assessment, as results that rely solely on large-scale spatial overlap may overestimate risk associated with fisheries. However, as Campbell Albatross spend approximately half of their

time foraging outside New Zealand's EEZ, conservation and fisheries management for this species requires a multi-national focus.

Key words: seabird-fishery interactions, Campbell Albatross, New Zealand EEZ, bivariate Gaussian Bridge movement models, spatio-temporal overlaps, bycatch

## **Introduction**

Population declines in seabirds, particularly albatrosses and petrels, have been attributed to fisheries-related mortality from accidental bycatch (Brothers 1991; Nel et al. 2002; Sullivan et al. 2006; Rolland et al. 2010; Anderson et al. 2011). Globally, it is estimated that tens of thousands of seabirds are killed every year – levels of mortality which are unsustainable. However estimates of fisheries-related mortality vary greatly by location and among species (Lewison and Crowder 2003; Anderson et al. 2011), and risk of bycatch is known to vary within species as a function of sex, age, and inter-individual differences in foraging site preference and behaviour (Nel et al. 2002; Votier et al. 2010; Tuck et al. 2015).

Conservation efforts to reduce seabird bycatch have been aided by identifying regions of seabird-fishery overlap to inform mitigation measures. Recently, bird-borne tracking has been used in tandem with spatially explicit fisheries data to better quantify the nature and extent of spatio-temporal overlap (Votier et al. 2010; Granadeiro et al. 2011; Torres et al. 2011; Catry et al. 2013; Torres et al. 2013a; Votier et al. 2013; Bodey et al. 2014; Collet et al. 2015; Patrick et al. 2015). Various scales of analysis have been applied to seabird-fisheries overlap and have highlighted contrasting results, in some cases due to the resolution of the data as well as our limited ability to distinguish between interactions and overlap events (e.g. (Torres et al. 2013a). Thus, combining and contrasting multiple spatial and temporal scales may

provide complementary information necessary to enhance our understanding of the true nature of seabird– fishery interactions.

In the present study, we examine the spatial and temporal overlap between fisheries vessels and the vulnerable Campbell Albatross *Thalassarche impavida*. Following a decline of 72% from 1966-1984 (Waugh et al. 1999), the population has been comparatively stable, with some suggestion of a slight decrease (Sagar 2014). In common with other species of albatross, the steep population decline coincided with increased fisheries effort in the Southern Ocean and variation in abundance has been attributed to the development of long-line and trawl fisheries within the foraging range of these birds (Waugh et al. 1999; Moore 2004; Sagar 2014). Campbell Albatross, and the closely related Black-browed Albatross *T. melanophris*, were regularly drowned by trawl fisheries and caught by longline vessels (Murray et al. 1993; Croxall and Gales 1998; Gales et al. 1998). Thus, our goal was to estimate the degree of spatio-temporal overlap between fisheries and breeding Campbell Albatross within New Zealand’s Exclusive Economic Zone (EEZ), to provide an updated understanding of bycatch risk in these waters and compare results at multiple spatio-temporal resolutions.

We used two approaches to identify potential interactions between fisheries and Campbell Albatross during the breeding season. First, we used a novel method, bivariate Gaussian bridges (BGB), to estimate the space use of both birds and vessels during the complete time of tracking. This allows us to calculate the area of the EEZ used by albatrosses and vessels, as well as to estimate how often albatrosses and fisheries use the same area at multiple temporal scales. These results can be aggregated over time, such as breeding stage or season, which provides estimates similar to population-level or multi-species assessments of overlap between fishing activity and species distribution (e.g. kernel density analysis by (Phillips et

al. 2006). If overlap between albatrosses and vessels occurs at the same time, this technique produces results comparable to the fine-scale tracking data on Black-browed Albatross and fisheries in waters around the Falkland Islands (Granadeiro et al. 2011, Catry et al. 2013). However, instead of using straight-line interpolation (and its associated assumptions) with (Torres et al. 2011) or without (Granadeiro et al. 2011) spatial buffers, we modelled motion variance, both parallel and orthogonal, to depict movement and space use more accurately. Second, since recent work has shown that birds may change their behaviour in response to fishing vessels, even as far away as 30 km (Bodey et al. 2014, Collet et al. 2015), we investigated events during which albatrosses were in proximity to fishing vessels and explored differences in overlap as a function of the spatial scale over which fishing vessel occurrence may affect bird behaviour. These seabird-vessel overlaps may indicate potential interactions, as spacing between seabirds and vessels may fluctuate at shorter time periods than were recorded (e.g. < 10 minutes). This is similar to the results estimated by buffering known locations by distance and/or time (i.e. (Votier et al. 2010; Patrick et al. 2015). Whenever we identified such a potential interaction event, we investigated whether the frequency of bird-boat interactions was explained by sex, stage of reproduction (incubation and chick-brooding), and between two years. Because albatrosses have shorter foraging trips during chick brooding, and therefore spend more time in the EEZ (Sztukowski 2016), we expected that there would be more interactions with fisheries during this stage compared with incubation. Furthermore, because female Campbell Albatrosses tend to use areas that are closer to the New Zealand mainland than males (Sztukowski 2016), we hypothesise that females are more likely to encounter fishing vessels within the EEZ. Therefore, by examining albatross–fishery overlap as a function of variations in distance between birds and boats, we may increase our understanding of the factors, such as breeding stage and sex, that impact

interactions at various spatial scales, with concomitant implications for assessing risk of bycatch.

## **Methods**

### **Albatross tracking**

We studied the endemic Campbell Albatross on Campbell Island, New Zealand (52°32'24"S, 169°8'42"E) during two breeding seasons (10 November 2011 to 29 December 2011, and 19 October 2012 to 27 December 2012; hereafter referred to as study years 2011 and 2012 respectively). To record movement behaviour, we attached modified GT-600 i-gotU GPS loggers (Mobile Action Technology, New Taipei City, Taiwan) to the central back feathers of incubating and chick brooding adults using Tesa© tape. GPS loggers were modified by removing the external plastic housing, and then sealed with heat shrink tubing (FiniShrink, UK) to waterproof each unit. The loggers weighed 33 g, approximately 1.1% of albatross body mass, and were set to record location every 10 minutes. Birds were re-captured on the nest following one or more complete foraging trips, as determined by nest attendance surveys. During capture, a small aliquot (~0.05 ml) of blood was taken from each individual for molecular sexing (Avian Biotech, Truro, Cornwall) under permit from the New Zealand Department of Conservation.

### **Vessel monitoring system**

We acquired data on the distribution and movement of fishing vessels via ship-borne GPS transponders provided by the New Zealand Ministry of Fisheries fishing vessel-monitoring system (VMS). Data were obtained for the same temporal period and spatial extent as the bird tracks (i.e., 10 November 2011 to 29 December 2011 and 19 October 2012 to 27 December 2012). These data covered all fishing vessels >28 m in length operating within the New Zealand EEZ. Additionally, smaller vessels fishing for Orange Roughy (*Hoplostethus*

*atlanticus*) or New Zealand Scampi (*Metanephrops challenger*) were also tracked. VMS transponders record vessel identification, speed, and location every 1 to 2 hours; gear type was not reported. Catch-effort data for our study period lacked the usual corresponding information needed to combine datasets. Catch-effort data also have low accuracy of event locations with unknown error (Torres et al. 2011), and thus were not used in our analyses. VMS data for areas outside the New Zealand EEZ were not available. Our analyses are therefore restricted to overlaps between albatrosses and VMS enabled vessels within the New Zealand EEZ, representing 49.7% of the 28,814.9 hours during which we logged Campbell Albatrosses on foraging trips.

## **Data Analysis**

### *Spatio-temporal overlap between foraging albatrosses and fishing vessels within the EEZ*

We used bivariate Gaussian bridge (BGB) movement models to calculate the temporally explicit space use of both foraging Campbell Albatrosses and fisheries vessels to examine their encounter probabilities. The advantage of BGBs over classic measures of utilization distributions, such as convex polygons, or kernel home range, is that they track movement heterogeneity across time and use two directional components instead of one to gain more precise estimates of the space utilized by individual animals/vessels. Moreover, space use between any two locations can be computed separately, allowing for temporally explicit estimates of the utilization distribution (Kranstauber et al. 2014). This allowed us to calculate the spatial overlap between foraging albatrosses and fishing vessels contemporarily, and in contrast to previous studies examining the interaction between seabirds and fisheries (e.g. Granadeiro et al. 2011; Torres et al. 2011), we can determine space use directly from the movement rather than relying on linear interpolation with or without a buffer zone. The use of BGBs should thus provide more accurate results of spatio-temporal overlap.



To prepare the tracking data, we split the VMS data into separate fishing trips with the same format as the albatross data; each fishing vessel trip was defined as a series of GPS fixes that were separated by a maximum of 24 hours. To prevent computational issues with birds and fishing vessels crossing the international dateline we shifted the dateline of the data by 180 degrees prior to all analyses.

#### *Coarse-scale spatio-temporal overlap between albatross and fisheries*

First, we calculated the total area utilized by each individual albatross and vessel to estimate the total spatial overlap during the complete study period (10 November 2011 to 29 December 2011, and 19 October 2012 to 27 December 2012). This coarse-scale spatio-temporal index is similar to population-level or multi-species assessments of overlap between fishing activity and species distribution (e.g. Phillips et al. 2006). We calculated the total space use of birds and fishing vessels during each foraging/fishing trip by computing BGBs on each complete trip, assuming a spatial location error of the GPS-devices of 18m for both the albatross data loggers and the VMS units of the vessels (Duncan et al. 2013). From these, we extracted the 95% estimates of total space use with a spatial resolution of 5 km, and re-projected them to an equal-area projection. We then combined the space use estimates for all bird foraging trips and fishing vessel trips separately, and calculated the coarse-scale spatial overlap of these population-level space use estimates.

#### *Fine-scale spatio-temporal overlap between albatross and fisheries*

Secondly, we investigated whether birds and vessels shared similar areas during the same time period, creating a potential for interactions. To do so, we split the BGB for each albatross and vessel trip into its smallest temporal units: the space use between two consecutive locations (i.e. every ten minutes for albatrosses, every 2 hours for vessels). From these, we extracted the 95% utilization distributions with a spatial resolution of one square

kilometre. For each potential encounter (utilization distributions with overlapping time intervals), we calculated the spatial overlap of the distribution estimates to estimate the area that was shared in space and time.

*Distance between GPS-fix locations for albatross and fishing vessels: Sex, stage and year effects*

The assessment of spatio-temporal overlap using BGBs (above) estimates simultaneous space use of foraging albatrosses and fishing vessels, however fisheries vessels can alter the behaviour of foraging seabirds at greater spatial scales. It has been shown that Northern Gannets (*Morus bassanus*) alter their behaviour as a response to the presence of fishing vessels within a range of up to 11 km (Bodey et al. 2014), and Wandering Albatross (*Diomedea exulans*) up to a distance of 30 km (Collet et al. 2015). To encompass the full effects of fishing vessels on foraging Campbell Albatross, we determined potential interaction events by calculating the distance to fishing vessels that were close in space and time using known locations. This is similar to modelling fishing vessel activity using windows of time and distance employed previously to avoid the assumptions associated with linear interpolation (i.e. Votier et al. 2010) or adding buffers to known locations (Patrick et al. 2015). First, we calculated the rhomb line distance from every GPS-fix of an albatross to every fishing vessel GPS-fix recorded within two hours (the temporal resolution of VMS tracks). Analyses used the full data set as well as the subset of the data where albatross and fishing vessel were <11 km apart, assuming a conservative effect of the fishing vessel (Bodey et al. 2014); or <30 km apart (Collet et al. 2015).

To investigate the effect of sex and stage of reproduction on the likelihood of observing potential interactions, we modelled the minimum observed distances between albatross and any fishing vessel using linear mixed-effects models. The models included individual bird as

a random effect (to control for repeat samples from the same bird) with year, sex and stage of reproduction (incubation and chick brooding) as fixed-level factors. We also fitted the two-way interaction between sex and stage of reproduction, to determine whether any sex-specific effects of fisheries varied as a function of breeding stage.

## **Results**

Over the two breeding seasons, we collected data from 299 foraging trips made by 81 Campbell Albatrosses (43 males and 38 females; Table 1). The total area used by albatross within the EEZ was 291,128.2 km<sup>2</sup> (6.7% of the EEZ, representing 32.0% of the total area used by birds). The rest of their foraging took place in the Tasman Sea, Australian waters or in international waters (Fig. 1). For the fishing vessels (n=83), a total of 320,510 VMS fixes were recorded during the same period of time, of which 99.9 % were within the EEZ. Subsequent results are thus based upon the EEZ only.

During their foraging trips, the albatrosses used a mean of  $3,835.1 \pm 5,930.2$  km<sup>2</sup> (mean  $\pm$  standard deviation; 95% home range) and travelled over distances of  $1,577.0 \pm 2,222.5$  km per trip (great-circle distances, see supplemental materials). Albatrosses spent 14,316.1 of the 28,814.9 hours within the EEZ (49.7 %).

### **Coarse-scale spatio-temporal overlap between albatross and fisheries**

During the tracking period, we found that Campbell Albatrosses and vessels spatially overlapped across 42,325.60 km<sup>2</sup> within the EEZ when overlaying the full 95% utilization distributions (pooled data). Despite albatross using 6.7% of the EEZ, they overlapped with fisheries vessels in just 0.97% of the EEZ, mostly in the south (Fig. 1).

### **Fine-scale spatio-temporal overlap between albatross and fisheries**

When calculating whether shared space use by albatrosses and fisheries occurred at the same time, we used the temporally explicit 95% utilization distributions and found no overlap between vessels and birds (Table 1). Overall, albatrosses used of 291,128.2 km<sup>2</sup> within the EEZ, and of this area, 42,325.6 km<sup>2</sup> were also utilized by fishing vessels (supplemental materials).

### **Distance between GPS-fix locations for albatross and fishing vessels: Sex, stage and year effects**

The minimum distance between GPS-fix locations of albatrosses and fishing vessels on foraging trips was significantly affected by breeding stage and year (Table 1). However, when using all spatial and temporal distances within 11 km and two hours of at least one vessel, albatrosses only overlapped during 17 of the 299 foraging trips (5.7%; Table 2). These 17 trips were performed by 15 individual birds that were within 11 km and two hours of a fishing vessel (range 1-8 vessels) at some stage during their foraging trip. Under this analysis, year was marginally significant in the subset of foraging trips as all but one of these foraging trips occurred in 2012. Fisheries overlap was most common during incubation and, while sex had no significant effect, 12 of the 17 foraging trips with fisheries overlap were by males, which may be due to sample size (Table 2). Under the scenario of a vessel footprint of 30 km, albatross foraging behaviour was potentially affected by fishing vessels on 25 foraging trips (8.4%) made by 21 individuals. Eighty percent of those foraging trips occurred during incubation with a sex ratio of 9:16 (female:male). The maximum number of vessels an individual potentially encountered increased from 8 within the 11 km footprint to 11 within the 30km footprint. When testing the larger (30 km) footprint, sex, breeding stage and year were not significantly associated with the minimum distance between albatrosses and fishing vessels. In most cases, the period of overlap between Campbell Albatrosses and vessels lasted

less than 10% of the foraging trip within the EEZ (Table 2). However a few individuals spent up to 65% of the foraging trip near vessels.

## **Discussion**

We provide the first estimate of the degree of association between fisheries and breeding Campbell Albatross using a novel BGB analysis at both coarse and fine spatio-temporal scales. Despite Campbell Albatrosses utilizing 6.7% of the New Zealand EEZ, they only overlapped with fishing vessels in a remarkably small section in the southern portion of the EEZ (0.97% of the area). Furthermore, we found very limited spatio-temporal overlap suggesting that albatrosses and vessels may occupy the same areas, but seldom at the same time. These results suggest that during the breeding season the risk of fisheries bycatch for Campbell Albatross is low within the New Zealand EEZ. In addition, this reveals that fishing vessels are not always important as foraging opportunities for albatrosses. Below we discuss the implications of these findings for studying seabird–fishery interactions in general and for the Campbell Albatross in particular.

Spatial area of overlap between albatross and vessels within the EEZ not only varied strongly depending upon the spatio-temporal resolution used, the assumed vessel footprint, and showed variation by sex and breeding stage. When accounting for an 11 km footprint (Bodey et al. 2014), we found overlap in 5.7% of trips, and these overlap periods generally lasted less than 10% of the trip within the EEZ. However a few individuals show substantial the spatio-temporal overlap and they may be at a higher risk of mortality. When we expanded this area to 30 km, assuming that Campbell Albatrosses may behave like Wandering Albatrosses (Collet et al. 2015), we found the potential for interactions increased to 8.4% of foraging trips. We expected females to have a higher risk of fisheries interactions based on time spent in proximity to the New Zealand mainland, where the highest fishing activities occur, but,

280 contrary to our expectations, 12 of the 17 foraging trips within 11 km of fisheries vessels  
281 were by males. Further investigation is needed to determine if the skewed sex ratio is due to  
282 the small number of foraging trips with seabird-fisheries overlap or represent different  
283 survival probabilities as well as examining behavioural responses to assess if Campbell  
284 Albatross are attracted to vessels, avoid them, or co-occur/use the same habitat.

285 Campbell Albatross is a “High Risk” species within New Zealand waters, based upon a semi-  
286 quantitative assessment of spatial overlap, observed captures, and fishing effort to assess  
287 fisheries vulnerability (Ministry for Primary Industries 2014). Prior to 1998, information on  
288 bycatch rates for Campbell Albatross was limited, as they were considered a subspecies of  
289 Black-browed Albatross (Robertson and Nunn 1998; Sangster et al. 2013); thus bycatch rates  
290 prior to 1998 were often a combination of Campbell and Black-browed Albatrosses. From  
291 1989 to 1995, bycatch of Campbell Albatrosses in Australian waters was estimated at 780 per  
292 year (Gales et al. 1998), and thus could have had serious impacts on the estimated 24,600  
293 annual breeding pairs in 1995-1998 (Moore 2004; Sagar 2014). Bycatch rates in this longline  
294 tuna fishery were higher (up to 1.26 birds per 1000 hooks) in summer than in winter, and  
295 skewed toward juveniles. Murray et al. (1993) reported declines in bycatch in New Zealand  
296 waters from 3662 seabirds in 1988 to 360 seabirds in 1992, suggesting mitigation measures  
297 may have reduced bycatch. Alternatively individuals that associated with fishing vessels  
298 could have been removed from the population, limiting the number of albatross around  
299 vessels (Tuck et al. 2015). More recently, there were zero to three observed captures of  
300 Campbell Albatross per year from 2004 to 2013 (Abraham E. R., Thompson F. N). Thus,  
301 current annual estimates of potential fatalities for Campbell Albatrosses within New Zealand  
302 waters range from 44 to 356 birds ((Ministry for Primary Industries 2014)); 0.20 – 1.69% of  
303 the estimated breeding population 2006-2012 (Sagar 2014). Most of the bycatch is associated  
304 with surface longline fisheries (Ministry for Primary Industries 2014). Observed captures

from trawls were associated with fisheries for Hoki (*Macruronus novaezelandiae*), Arrow Squid (*Nototodarus sloanii*, *N. gouldi*), New Zealand Scampi and Southern Blue Whiting (*Micromesistius australis*), and occurred outside the incubation and chick brooding stages (Abraham and Thompson 2012). If we assume that there are 21,648 individuals foraging at any one time, then over our study time period, we could expect up to 1803 albatross foraging trips to overlap with fishing vessels within New Zealand's EEZ (8.4 % of trips within 30 km footprint). Although it is unknown how many interactions with fishing vessels result in mortalities, these low bycatch rates agree well with the low overlap rates and lack of spatio-temporal overlap recorded in our tracking study. During the Austral summers of 2011/12 and 2012/13, Campbell Albatross spent about half their time foraging within the EEZ, however, the rest of their foraging took place in areas without available vessel monitoring data, mostly in the Tasman Sea or Australian waters. Thus, by focusing on VMS data within New Zealand's EEZ we probably underestimate the frequency of overlap between Campbell Albatross and fishing vessels, and our results are limited to the breeding season. Campbell Albatross may be vulnerable to fisheries related mortality in areas not studied here, and at different ages and breeding stages (Murray et al. 1993; Gales et al. 1998), but our tracking data is consistent with other sources of data indicating that bycatch risk of adult Campbell Albatross within the New Zealand EEZ is low during the breeding season.

There are a number of factors that may impact the nature of interactions between seabirds and fisheries, including the presence and timing of discards, the use of mitigation measures, weather, inter-species competition and the availability of other resources (Votier et al. 2008; Dietrich et al. 2008; Jiménez et al. 2009; Favero et al. 2011; Croxall et al. 2013). On the Patagonia Shelf, the frequency of Black-browed Albatross-fisheries interactions was associated with wind conditions, season, time of day, and the presence of discards (Favero et al. 2011). Management of discards, such as offal mincing, reducing discharge to sump water,

or waste holding/batch discharge, can reduce the abundance of seabirds around fisheries vessels, with concomitant reductions in mortality risk (Abraham et al. 2009; Pierre et al. 2010). Additionally, mitigation measures, such as night setting, weighted lines and Tori lines, have reduced bycatch rates and may also deter seabird-fisheries interactions (Løkkeborg 2003; Dietrich et al. 2008). Inter-species competition may also reasonably account for the low interaction rates since fisheries within New Zealand's EEZ frequently kill other albatross species. White-capped Albatross (*Thalassarche steadi*), for example, regularly attend fishing vessels in New Zealand waters and may out-compete Campbell Albatross (Bartle 1991; Torres et al. 2011). Annual variation in these factors combined with environmental variation could account for annual influences found in our models; for example, the area utilized during foraging trips was larger during 2012.

### **Conservation implications**

Our results suggest that, because of the limited overlap between Campbell Albatross and fisheries in New Zealand waters during the breeding season, the risk of bycatch is relatively low. Moreover, examining coarse-scale spatio-temporal overlap with fisheries may provide an overestimate of risk if not accounting for fine-scale temporal components that may be further reduced if behavioural state of the bird is added. These finer scale analyses of spatio-temporal overlap may both improve risk assessments and provide insight into foraging behaviour (Votier et al. 2010; Granadeiro et al. 2011; Croxall et al. 2013; Torres et al. 2013a; Torres et al. 2013b). While BGBs provide an excellent new tool to examine movements and overlaps between animals and fishing vessels, they require spatially and temporally explicit data. The regional focus of our study was constrained due to lack of data, thus reinforcing the need to increase the availability of high resolution fisheries data. Current estimates suggest that the population of Campbell Albatross is slightly declining or stable (Waugh et al. 1999; Sagar 2014). If declines continue without an increase in bycatch, other factors such as food



availability or environmental change should be carefully assessed. More importantly, conservation and fisheries management for this species needs to occur across all age-classes and on a multi-national scale, as juvenile Campbell Albatross may be more vulnerable to bycatch, and adult albatrosses spend half of their time foraging outside New Zealand waters. The timing and duration of mitigation measures could be improved by incorporating fine-scale spatio-temporal distributions into dynamic ocean management, in which management efforts to reduce bycatch change in response to spatial and temporal alteration in the ocean or species movements rather than largely static marine conservation areas (Howell et al. 2008; Hobday et al. 2010; Hobday et al. 2014).

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379 **Compliance with ethical standards**

380 **Conflict of interest** The authors declare that they have no conflict of interest. All applicable  
381 international, national, and/or institutional guidelines for the care and use of animals were  
382 followed. All scientific procedures and site access were conducted under permit issued by the  
383 New Zealand Department of Conservation and was approved by the animal ethics committee  
384 at the Plymouth University. Great care was taken to minimize stress to the animals during  
385 handling.

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Table 1. The effects of sex, breeding stage, and year on the minimum distance between Campbell Albatross and fishing vessels using linear mixed-effects models. Models included individual bird as a random effect (to control for repeat samples from the same bird).

Distance Between Albatross and Fishing Vessels (Full Dataset)				Distance Between Albatross and Fishing Vessels (Within 2 hours and $\leq 11$ km)			
	DF	F-value	p-value		DF	F-value	p-value
Intercept	17659	3882.03		Intercept	21	23.94	
Sex	79	0.16	0.69	Sex	12	0.38	0.55
			<0.000				
<b>Stage</b>	17659	572.41	1	Stage	21	0.019	0.92
<b>Year</b>	17659	6.57	0.01	<b>Year</b>	12	4.73	0.05
Sex*Stage	17659	2.28	0.13				

Distance Between Albatross and Fishing Vessels (Within 2 hours and $\leq 30$ km)			
	DF	F-value	p-value
Intercept	55	59.39	
Sex	18	1.70	0.21
Stage	55	1.04	0.31
Year	18	0	0.98

Table 2. Interaction characteristics of foraging trips within 11 km or 30 km and 2 hours of fishing vessel location.

Individual	Foraging Trip	Sex	Stage	Year	Within 11 km and 2 hours			Within 30 km and 2 hours		
					Number of Vessels	Number of Locations	Proportion of Trip	Number of Vessels	Number of Locations	Proportion of Trip
1	1	Female	Incubation	2011	0	0	0	1	7	0.00
2	2	Female	Incubation	2012	0	0	0	4	8	0.00
3	3	Female	Incubation	2012	8	103	0.04	11	232	0.09
3	4	Female	Incubation	2012	6	246	0.14	6	506	0.30
3	5	Female	Chick Brooding	2012	0	0	0	3	6	0.02
4	6	Female	Incubation	2012	0	0	0	3	32	0.02
4	7	Female	Incubation	2012	1	7	0.01	1	18	0.02
5	8	Female	Incubation	2012	1	3	0.00	7	46	0.03
6	9	Female	Incubation	2012	1	2	0.00	1	30	0.01
7	10	Male	Chick Brooding	2011	1	2	0.00	1	11	0.01
8	11	Male	Incubation	2012	0	0	0.00	4	28	0.01
9	12	Male	Incubation	2012	6	962	0.49	7	1274	0.65
10	13	Male	Incubation	2012	1	5	0.01	1	53	0.10
10	14	Male	Chick Brooding	2012	2	17	0.05	3	71	0.20
11	15	Male	Incubation	2012	1	11	0.01	1	20	0.01
12	16	Male	Incubation	2012	1	21	0.01	5	50	0.02
13	17	Male	Chick Brooding	2012	1	39	0.14	1	65	0.23
14	18	Male	Incubation	2012	1	15	0.01	2	32	0.01
15	19	Male	Incubation	2012	1	53	0.02	3	122	0.04
16	20	Male	Incubation	2012	1	1	0.00	1	12	0.00
17	21	Male	Incubation	2012	0	0	0	2	22	0.01
18	22	Male	Incubation	2012	0	0	0	1	5	0.00
19	23	Male	Chick Brooding	2012	0	0	0	1	16	0.04

20	24	Male	Incubation	2012	3	23	0.02	6	107	0.07
21	25	Male	Incubation	2012	1	3	0.00	1	12	0.00

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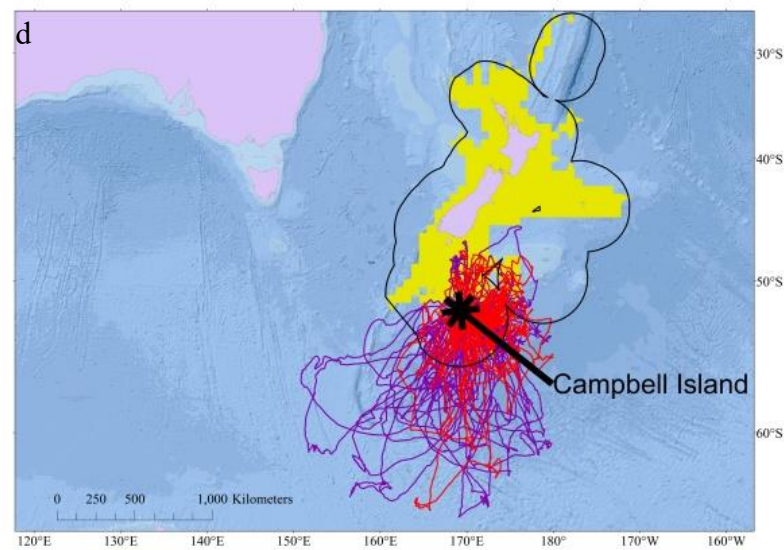
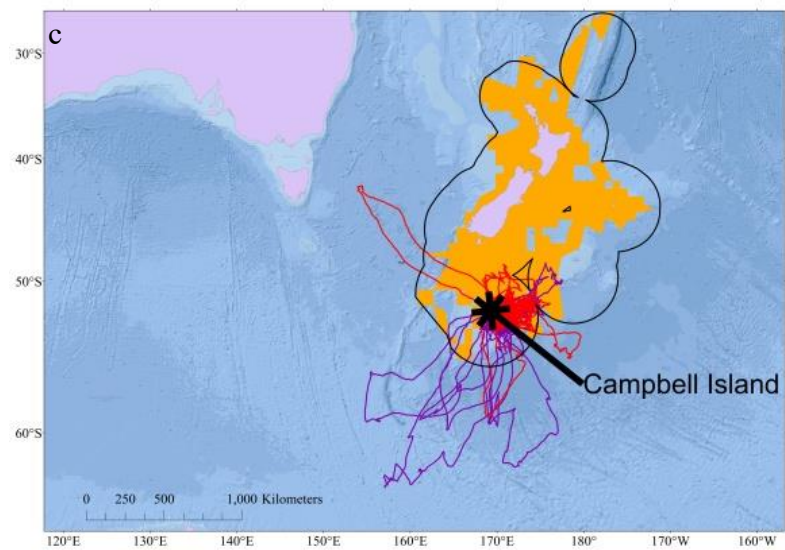
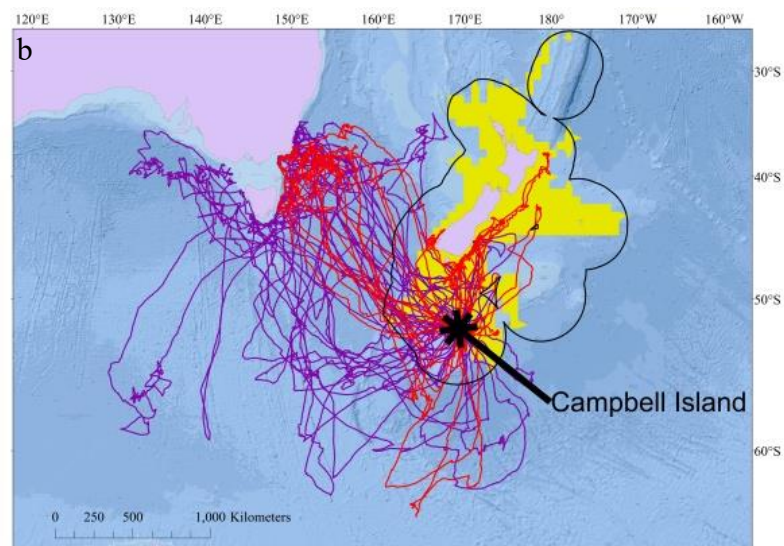
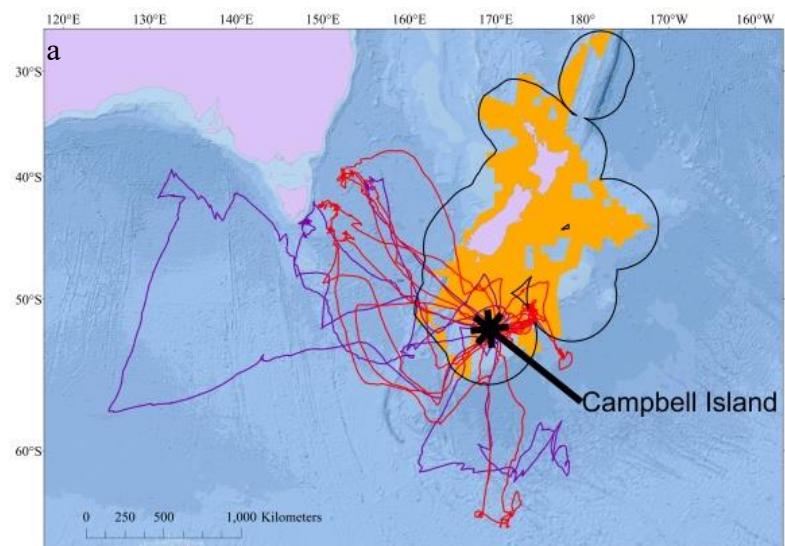


Fig. 1. Spatial overlap between fishing vessels (2011: orange, 2012: yellow) and foraging trips within New Zealand's Exclusive Economic Zone (black) during: a) incubation in 2011 (n=18), b) incubation in 2012 (n=41), c) chick brooding during 2011 (n=79) and d) chick brooding during 2012 (n=161). Foraging trips were undertaken by females (red) and males (purple). Vessel monitoring data were transformed into a polygon.

Supplemental material. Distance travelled and spatial utilization (area) per foraging trip (mean  $\pm$  standard deviation) for Campbell Albatrosses within New Zealand's Exclusive Economic Zone (EEZ). Data are sub-divided by sex and stage of reproduction (incubation or chick brooding).

Sex	Year	Stage	Number of Trips	Number of Individuals	Area (km <sup>2</sup> )	Distance Travelled (km)	Time Inside EEZ (hours)	Time Outside EEZ (hours)
Female	2011	Incubation	12	11	2149.8 $\pm$ 1222.7	2482.3 $\pm$ 1858.5	23.4 $\pm$ 33.5	48.7 $\pm$ 100.2
Female	2012	Incubation	16	13	3048.7 $\pm$ 2618.0	3892.9 $\pm$ 3013.3	55.3 $\pm$ 97.7	152.0 $\pm$ 168.2
Female	2011	Chick Brooding	44	15	1172.7 $\pm$ 737.2	639.4 $\pm$ 602.8	35.1 $\pm$ 19.1	17.0 $\pm$ 28.6
Female	2012	Chick Brooding	80	27	1375.3 $\pm$ 1088.3	843.6 $\pm$ 784.8	23.2 $\pm$ 18.5	15.4 $\pm$ 22.0
Male	2011	Incubation	6	6	1570.7 $\pm$ 870.4	3552.8 $\pm$ 3441.1	25.3 $\pm$ 20.3	166.2 $\pm$ 101.7
Male	2012	Incubation	25	24	2466.5 $\pm$ 1244.7	5558.9 $\pm$ 4159.6	35.5 $\pm$ 55.5	217.9 $\pm$ 165.4
Male	2011	Chick Brooding	35	11	1112.6 $\pm$ 656.5	805.0 $\pm$ 875.9	35.8 $\pm$ 31.9	27.0 $\pm$ 28.5
Male	2012	Chick Brooding	81	27	1372.9 $\pm$ 935.1	1117.3 $\pm$ 973.0	20.5 $\pm$ 16.3	34.5 $\pm$ 31.4